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FOOT ORTHOSES INDUCE IMMEDIATE CHANGES IN LOWER LIMB NEUROMOTOR CONTROL OF GAIT IN PEOPLE WITH PATELLOFEMORAL JOINT OSTEOARTHRITIS: A PILOT STUDY

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Purpose: Considering that patellofemoral joint osteoarthritis (PFJ OA) can cause greater symptoms and functional limitations than similar levels of radiographic tibiofemoral joint (TFJ) OA, it is important to identify effective interventions that are targeted to PFJ dysfunction. Disturbances in lower limb muscle timing and/or peak force have been identified in those with PFJ OA. Given that foot orthoses have been shown to address these muscle imbalances in asymptomatic controls, as well as improve pain and reduce components of foot pronation in people with PFJ OA, it is plausible that they may induce changes in lower limb neuromotor control in people with PFJ OA. The aim of this pilot study was to evaluate the immediate effects of foot orthoses on neuromotor patterns of the hip, knee and ankle muscles in people with PFJ OA.

Methods: A within-subjects, repeated measures trial utilised participants with PFJ OA from a larger randomised clinical trial (age $>$ 40 years; PFJ osteophytes on skyline radiographs; anterior knee pain during PFJ loading e.g. steps or squatting; TFJ OA K&L grade $<$3). Baseline pain severity during walking (visual analogue scale 0-100mm) and the Knee Injury and Osteoarthritis Outcome Score (KOOS; 100-0) were recorded to characterise the cohort. Electromyographic (EMG) data were collected during 10 walking trials (self-selected speed) under two conditions: i) shoes (Nike Strap Runner); and ii) shoes with prefabricated foot orthoses (Vasyli International). EMG recordings from 12 lower limb muscles (gluteus maximus, gluteus medius, rectus femoris, tensor fascia lata, medial hamstrings, lateral hamstrings, vastus medialis obliquus (VMO), vastus lateralis (VL), medial gastrocnemius (MG), lateral gastrocnemius (LG), soleus, tibialis anterior) were collected using pairs of Ag/AgCl surface electrodes (Motion Laboratory Systems), and sampled at 1080Hz (Biotel). EMG onset and offset times, expressed as a percentage of stride time (%ST), were identified with customised software (Matlab) from the average of four trials. Paired t-tests ($p = 0.05$) determined differences between conditions. Data are presented as mean difference [95% confidence interval].

Results: Nine participants were included (6 female; age 52 $\pm$ 6 years; baseline walking pain 1.3 $\pm$ 1.1cm; KOOS pain 68 $\pm$ 21, symptoms 69 $\pm$ 15, activities of daily living 80 $\pm$ 14, sport/recreation 62 $\pm$ 18, quality of life 55 $\pm$ 16). The onset of VL and lateral hamstrings EMG was significantly later when walking with foot orthoses than when walking with shoes alone (VL: 1.7 [0.01 to 3.4] %ST; LH: 8.1 [0.05 to 16.3] %ST). Offset of MG and LG EMG was later when walking with foot orthoses than walking with shoes alone (MG: 2.9 [0.7-3.8] %ST; LG: 2.2 [2.6-4.1] % ST). No other significant differences were identified between conditions, although a non-significant trend towards later offset of gluteus medius when walking with foot orthoses was noted.

Conclusions: This pilot study indicates that individuals with PFJ OA exhibit immediate changes in neuromotor control in response to a foot orthoses intervention. Interestingly, a later onset of VL and lateral hamstrings EMG was observed when walking with foot orthoses compared with shoes only. In PFJ pain conditions, earlier onset of VL and lateral hamstrings relative to VMO and medial hamstrings has been proposed to influence lateral tracking of the patella. Thus, the identification of a later onset of these muscles with foot orthoses may have important positive implications for PFJ loads. Furthermore, this may provide a mechanism by which foot orthoses reduce pain associated with PFJ OA. Delayed offset of the gastrocnemeii was also observed when walking with foot orthoses compared to shoes alone. Our earlier studies in PFJ OA found consistent and immediate reductions in rearfoot eversion and ankle joint dorsiflexion in response to foot orthoses. It is possible that prolonged gastrocnemeii activity could relate to these biomechanical changes as these muscles have a role in controlling both ankle joint dorsiflexion and rearfoot motion. Finally, the observation of a non-significant trend towards later offset of gluteus medius with foot orthoses is notable. Considering the importance of gluteus medius for maintaining hip and pelvis frontal plane alignment during stance phase, prolonged gluteus medius activation may reduce dynamic knee valgus and lateral patellar tracking. While this pilot study provides important preliminary information regarding immediate positive effects of foot orthoses on lower limb neuromotor control of gait in people with PFJ OA, further studies are required in larger cohorts to determine longer-term effects.

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JOINT CONTACT FORCE AT MEDIAL COMPARTMENT OF TIBIOFEMORAL JOINT DECREASES IN TOE-OUT GAIT

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Purpose: Modification of increased toe-out angle during walking is an accessible method to decrease the external knee adduction moment and thus mechanical stress at the medial compartment of the tibiofemoral joint (medial contact force). Stress in this compartment can cause damage to the articular cartilage of the knee. However, it is not clear how much the toe-out gait contributes to the decrease in mechanical stress. Inverse simulation analysis enables us to calculate the muscle tension force and the medial knee contact force by studying the joint angle and joint moment based on a musculoskeletal model. This study aimed to investigate the effect of increased toe-out angle on the medial knee contact force by using musculoskeletal simulation analysis.

Methods: Eighteen healthy subjects participated in this study (8 male, 10 female, average age 20.7 $\pm$ 0.8 years). Three-dimensional motion analysis measurements were taken during walking. The subjects were instructed to walk on the force plate; normally for the normal gait and pointing their feet outward for the toe-out gait on the force plate. The musculoskeletal model consists of four segments (pelvis, thigh, shank, and foot). The ankle, knee, and hip joints have 2, 1, and 3 degrees of freedom, respectively. The model has 42 Hill-model muscle tendon units. Muscle parameters were based on previous studies. The muscle tension force was calculated from the data on joint angles and joint moments by using the musculo-skeletal inverse simulation analysis. Subsequently, the medial contact force was calculated from the two force components caused by the muscle tension force and ground reaction force. Data regarding the joint moment and contact force from heel contact to toe-off was selected and normalized to 100% of the stance phase (%SP). Maximum knee adduction moment or medial contact force during 0%-50%SP was defined as the first peak; the maximum value of each during 51%-100%SP was the second peak. Each joint moment was normalized based on height (HT) and body weight (BW) of individual subjects, and the medial contact force was normalized BW. Surface electromyography (EMG) was recorded simultaneously with the three-dimensional gait analyses for comparison with the muscle activation based on inverse dynamic analyses. Electrodes were placed on the clean-shaven skin above four muscles (lateral gastrocnemius, medial gastrocnemius, vastus lateralis, and semimembranosus). Student's T-test was used to confirm whether the effects of the foot angle were appeared on the adduction moment and the medial knee contact force.

Results: The toe-out angle was 5.1 $\pm$ 7.0 degrees during the normal gait and 19.1 $\pm$ 8.0 degrees during the toe-out gait. During the toe-out gait, a tendency to decrease of gastrocnemius muscle activation during mid- and late-stance phase and increase of vastus lateralis activation during early stance phase in the results of both simulation and EMG was found. Both the first and second peaks of the adduction moment significantly decreased during the toe-out gait when compared to the normal gait (First peak: normal 3.62 $\pm$ 1.32 Nm/%BW*HT, toe-out 3.26 $\pm$ 1.20 Nm/%BW*HT; Second peak: normal 3.57 $\pm$ 1.17 Nm/%BW*HT, toe-out 2.61 $\pm$ 1.10 Nm/%BW*HT). The toe-out gait did not show a significant decrease in the medial knee contact force at the first peak (normal 1.91 $\pm$ 0.49 BW, toe-out 1.93 $\pm$ 0.43 BW); however, the toe-out gait showed a significant 12% decrease in the medial knee contact force at the second peak, compared to the normal gait (normal 1.97 $\pm$ 0.36 BW, toe-out 1.74 $\pm$ 0.36 BW).

Conclusions: The similarities in the EMG activity patterns and the simulation results show that simulation analysis is a valid method to estimate muscle activation and medial contact force. The results suggest that the toe-out gait can be used to decrease the second peak of the medial knee contact force.